International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 5, Issue 4, Aug 2015, 105-114

MODELING AND FINITE ELEMENT ANALYSIS OF A WALKING ROBOT LEG MECHANISM AT HIGH SPEEDS USING ADAMS SOFTWARE

MOHAMMED ABBAS F & GOPI KRISHNA

Department of Mechanical Engineering, Acharya Nagarjuna University, Guntur, India

ABSTRACT

In this project work study of feasibility for a fully rotating actuation of the pantograph- leg has been carried out. In particular, a suitable model of the leg kinematics analysis and design are presented pantograph-leg for walking machines. In particular, the motion capability of the leg has been studied, together with theoretical acceleration, velocity of the components of the mechanism. A parametric study has been also carried out in order to investigate the influence of some basic design parameters on its motion capabilities Simulation with MATLAB software have been carried out to verify the operation of the leg. The modeling also has been carried out by CATIA software . Structural analysis and FEM with ADAMS software also have been carried out to check the induced stresses during the operation of the mechanism.

KEYWORDS: Robots, Design, Dynamic & Stress Analysis, Walking Robot Leg, Pantograph and Chebyshev Mechanism, Four Bar Mechanism

INTRODUCTION

The walking in nature is a very flexible and complex task. For example, in generating a trajectory several parts/systems are involved: muscle as actuators, bones as linkages, nerves as sensors and brain as a complex control system. Moreover, locomotion type depends on several variables. For example, one of the most influent aspects can be considered the environment characteristics. While the legged locomotion is more adaptable in a wide range of ground, the wheeled locomotion is faster but only on smooth surfaces. The most common walking machines are wheeled and tracked systems, but large interest can be also focused on legged machines. In fact, existing mobile robots need regular terrain to move over; while legs are more flexible and could be used even in unknown environments. The complexity of legged machines increases as number of degrees of freedom increases in the mechanism of legs.

Being Mechanical Engineers We are very interested in designing of mechanisms. Generally most of Robots are moving with wheels, so we decided to make something new, so we choose to design the Robotic leg mechanism which is of low cost and easy operated. As design alone does not satisfy the purpose, and to get the required leg motion by using four bar mechanisms or pantograph mechanisms. So analysis has been performed in ADAMS for identifying the feasibility of design.

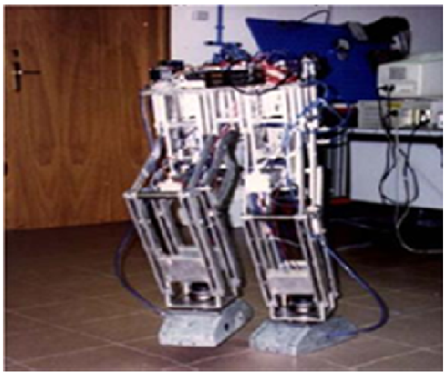


Figure 1: Ep-WAR II Robotic Leg

At LARM, the Laboratory of Robotics and Mechatronics in Casino biped walking robots EP-WAR and EP-WAR II have been designed and built with a suitable pantograph mechanism for the legs.

LITERATURE REVIEW

F. Pfeiffer, T. Zielinska: Walking: Biological and Technological Aspects, in this paper the analysis and design are presented for a 2-DOF (Degree-Of-Freedom) leg-wheel walking machine. A preliminary prototype of a low-cost robot, which is capable of a straight walking with only one actuator, has been designed and built experimental validation have been carried out to verify the operation of the prototype.

Song S. M., Lee J. K, Waldron K.J: Motion Study of Two and Three Dimensional Pantograph Mechanisms, In this paper, the mechanical efficiency of kinematics of Pantograph type manipulators are studied. The mechanical efficiency of pantograph mechanism and conventional open-chain and closed chain manipulators are studied and evaluated using the concept of modified geometric work .The kinematics of 6 D.O.F, pantograph type manipulators are studied and special mechanisms are introduced.

MODELING ROBOT LEG

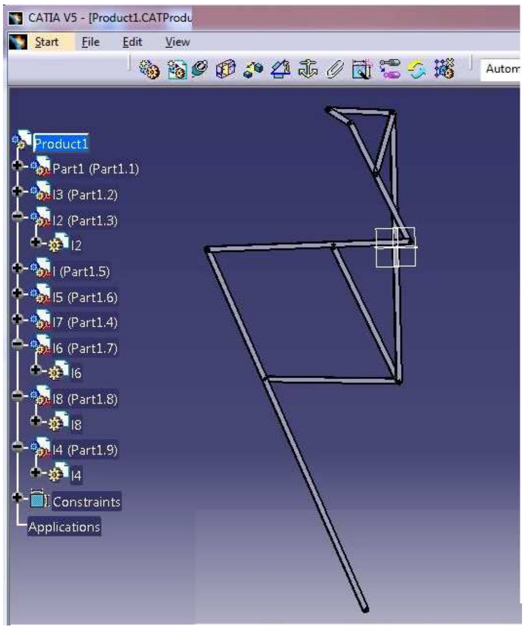


Figure 2: Robot Leg by Using CATIA V5

KINEMATIC ANALYSIS

A Kinematic analysis has been carried out in order to evaluate and simulate performances and operations of the leg system. A fixed reference system CXY has been considered attached at point C, as shown in Figure 3. The position of

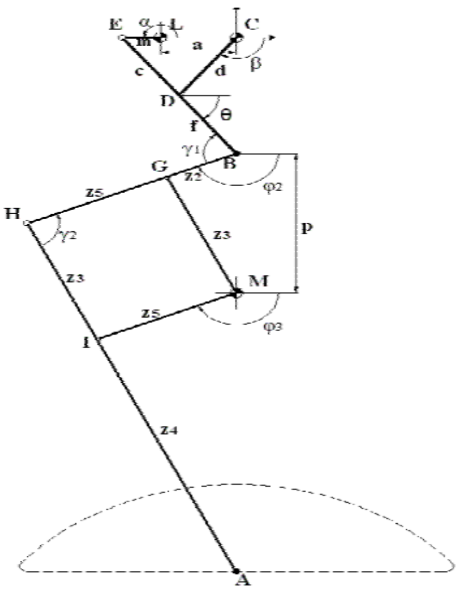


Figure 3: A Kinematic Scheme for the 1-DOF Leg

point B with respect to CXY frame can be evaluated as a function of the input crank angle α and kinematic parameters of the Chebyshev mechanism LEBDC in the form:

$XB= – a + m \cos\alpha + (c+f) \cos\alpha$ (1)

$YB= – m \sin\alpha – (c+f) \sin\theta$ (2)

The position of A with respect to the fixed frame can be given as:

$XA= XB – (z2+z4) \cos\varphi 2 + (z3+z5) \cos\varphi 3$ (3)

$YA= YB – (z2+z4) \sin\varphi 2 – (z3+z5) \sin\varphi 3$ (4)

The proposed analysis has been considered for numerical simulations.

In particular, numerical results have been obtained without considering the leg's interaction with the ground.

Table 1: Design Parameters in (mm) for the Kinematic Model of Fig

c=f=d=62.5	$a=z_2=50.0$
$b_1=75.0$	$b_2=150.0$
m=25.0	h=230.0
$z_2=50.0$	$z_3=z_6=110.0$
$z_4=220.0$	$z_5=z_7=100.0$

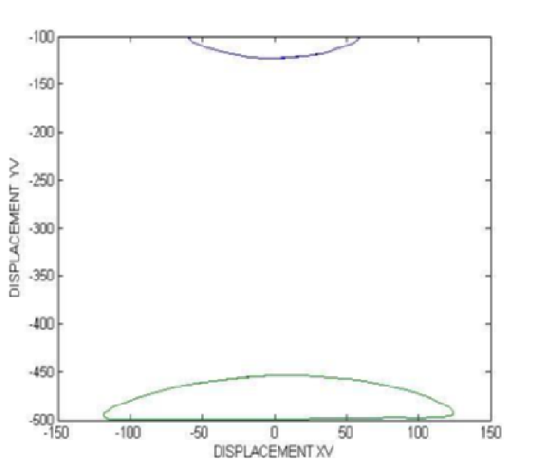
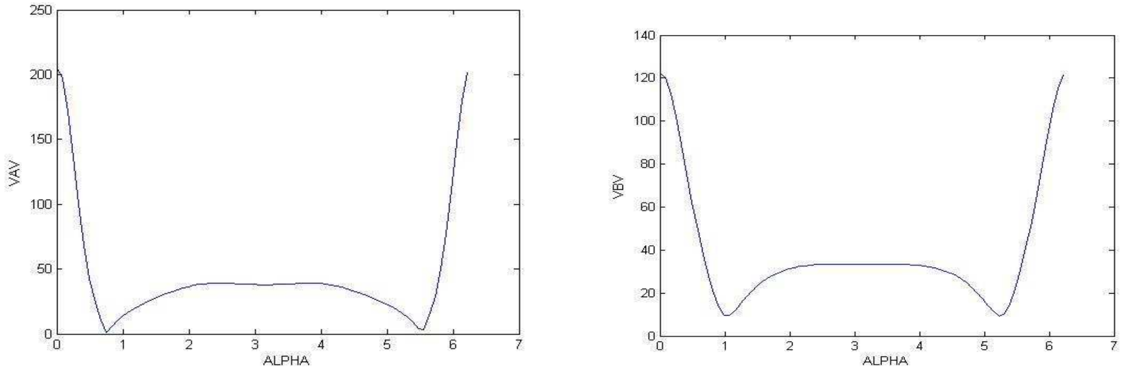


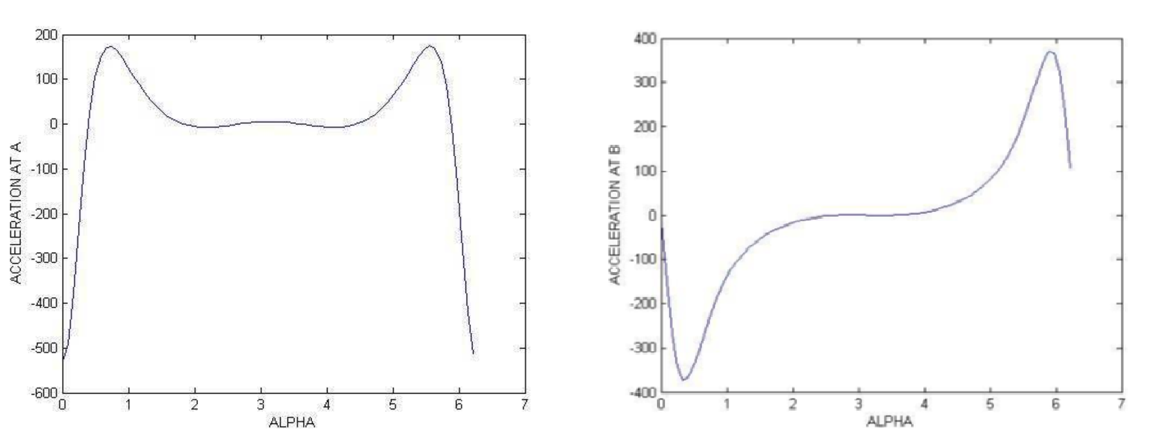
Figure 4: Numerical Simulation of Displacement (m) at Both Point A and Point B



(a) **(b)**

Figure 5: Numerical Simulation of Velocity: a) at Point b) at point B

Figure Shows Numerical Simulation of the Velocity of Point A & B when a Constant angular velocity has been considered



(A) (B)

Figure 6: Numerical Simulation of Acceleration: a) at point A b) at Point B

Figure 6 shows numerical simulation of the acceleration of point A & B when a constant angular velocity has been considered.

DYNAMIC and STRESS ANALYSIS

After modeling by using CATIA Software, now will insert the assemble modeling in ADAMS to get Dynamic analysis.

- **Material Properties**

Material Type	aluminum
Density	2.74E-006 kg/mm**3
Young's Modulus	7.1705E+004 newton/mm**2
Poisson's Ratio	0.33

Figure 7

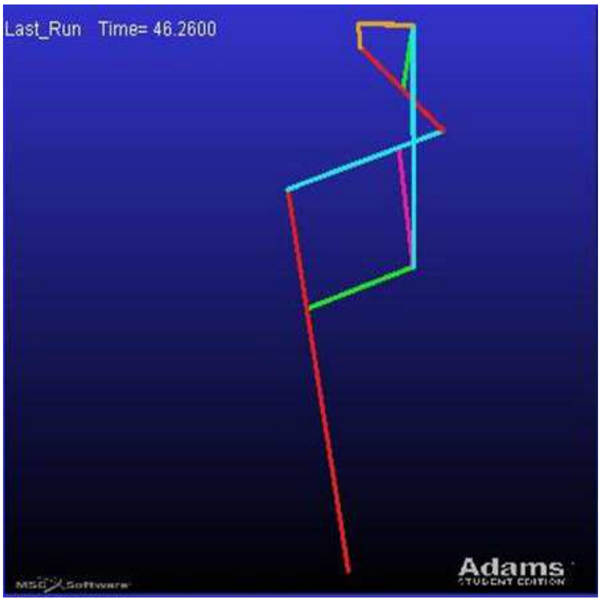


Figure 8: Robot Leg

Dynamic Analysis

In case four bar mechanisms, is an important to get analysis at A,B points, however, here will analysis by using ADAMS to get all information what are required in robot leg mechanism case. Here, will use various values of speed motion and analysis them to get velocity, displacement and acceleration plots.

Stress Analysis

- **Stress Analysis on Link Number 5, at N = 22 rpm.**

Table 2: Shows Stresses Values in Part 5, in N=22rpm

s Information

VON MISES Hot Spots for PART_5_flex Date=2015-03-19 09:42:37							
Model= .model_8		Analysis= Last_Run		Time = 0 to 20 sec			
Top 10 Hot Spots			Abs	Radius= 0.0 mm			
Hot Spot	Stress	Node	Time	Location wrt LPRF (mm)			
#	(newton/mm**2)	id	(sec)	X	Y	Z	
1	0.0363759	49	0.03	11.6063	133.358	10	
2	0.0344828	72	0.03	2.34629	151.089	-10	
3	0.0344055	73	0.03	11.6063	133.358	-10	
4	0.0318633	48	0.03	2.34629	151.089	10	
5	0.0317462	71	0.03	-6.91372	168.821	-10	
6	0.0310751	70	0.03	-16.1737	186.553	-10	
7	0.0294581	123	0.03	38.6037	124.866	-10	
8	0.0294345	47	0.03	-6.91372	168.821	10	
9	0.0276425	51	0.03	30.1263	97.8944	10	
10	0.027412	52	0.03	39.3863	80.1627	10	

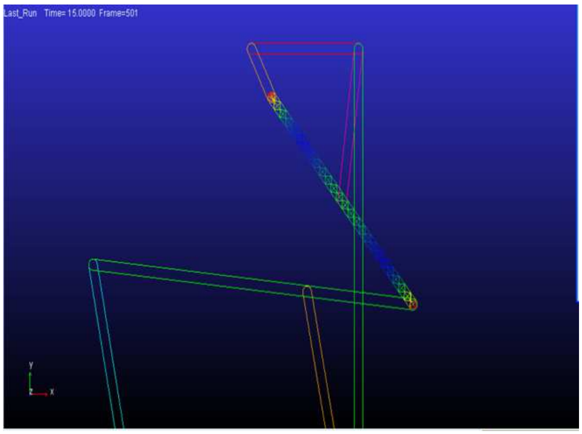


Figure 9: Stresses in Part 5 at N=22rpm

Model picture in ADAMS shows the stresses and positions of stresses.

- **Stress Analysis on Part (Link) Number 5, at N = 110 rpm.**

Table 3: Shows Stresses Values in Part 5, in N=110 rpm

Information

VON MISES Hot Spots for PART_5_flex Date= 2015-03-19 09:47:24						
Model= .model_8		Analysis= Last_Run		Time = 0 to 20 sec		
Top 10 Hot Spots			Abs	Radius= 0.0 mm		
Hot Spot	Stress	Node	Time	Location wrt LPRF (mm)		
#	(newton/mm**2)	id	(sec)	X	Y	Z
1	324.599	123	12.69	38.6037	124.866	-10
2	308.587	49	12.69	11.6063	133.358	10
3	292.383	73	12.69	11.6063	133.358	-10
4	289.803	72	12.69	2.34629	151.089	-10
5	284.874	99	12.69	38.6037	124.866	10
6	279.74	122	12.69	47.8637	107.135	-10
7	275.901	101	12.69	20.0837	160.33	10
8	272.855	98	12.69	47.8637	107.135	10
9	262.617	48	12.69	2.34629	151.089	10
10	262.064	71	12.69	-6.91372	168.821	-10

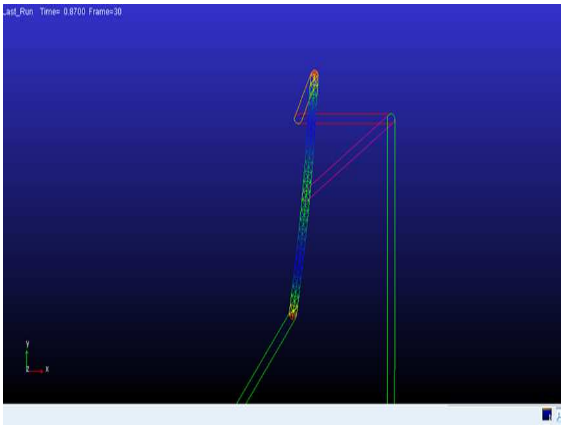


Figure 9: Fail in Robot Leg in Part 5 at N=110 rpm

Model picture in ADAMS shows the stresses and positions of stresses. It shows the fail in robot leg in part 5.

- **Stress Analysis on Link Number 9, at N = 22 rpm.**

Table 4: Shows Stresses Values in Part 9, in N=22 rpm

ots Information

VON MISES Hot Spots for PART_9_flex Date= 2015-03-19 09:44:58						
Model= .model_8		Analysis= Last_Run		Time = 0 to 20 sec		
Top 10 Hot Spots			Abs	Radius= 0.0 mm		
Hot Spot	Stress	Node	Time	Location wrt LPRF (mm)		
#	(newton/mm**2)	id	(sec)	X	Y	Z
1	0.0546985	283	0.05	-414.78	-521.761	10
2	0.0540403	357	0.05	-414.78	-521.761	-10
3	0.0519387	190	0.05	-433.909	-527.603	-10
4	0.0515919	192	0.05	-421.834	-565.745	-10
5	0.0511563	360	0.05	-432.893	-464.548	-10
6	0.0509357	117	0.05	-427.871	-546.674	10
7	0.0507529	204	0.05	-420.010	-502.69	10
8	0.0498485	116	0.05	-433.909	-527.603	10
9	0.0494026	287	0.05	-438.93	-445.477	10
10	0.0491059	356	0.05	-408.743	-540.832	-10

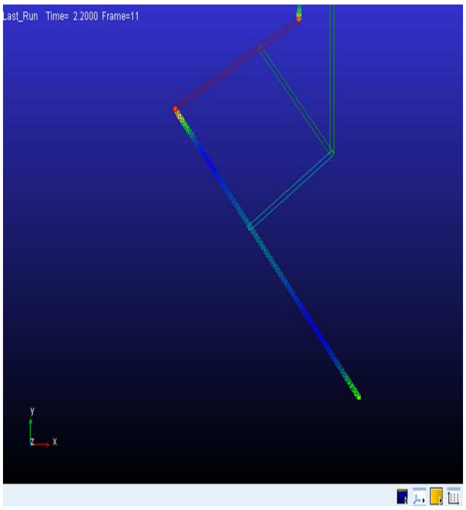


Figure 10: Stresses in Part 9 at N=22rpm

Model picture in ADAMS shows the stresses and positions of stresses.

- **Stress Analysis on Part (Link) Number 9, at N = 110 rpm.**

Table 5: Shows Stresses Values in Part 5, in N=110 rpm

Spots Information

VON MISES Hot Spots for PART_9_flex Date= 2015-03-19 09:48:33						
Model= .model_8		Analysis= Last_Run		Time = 0 to 20 sec		
Top 10 Hot Spots			Abs	Radius= 0.0 mm		
Hot Spot	Stress	Node	Time	Location wrt LPRF (mm)		
#	(newton/mm**2)	id	(sec)	X	Y	Z
1	96.3974	283	10.95	-414.78	-521.761	10
2	94.6793	357	10.95	-414.78	-521.761	-10
3	90.846	282	10.95	-408.743	-540.832	10
4	90.7652	190	10.95	-433.909	-527.603	-10
5	88.7673	192	10.95	-421.834	-565.745	-10
6	86.7231	356	10.95	-408.743	-540.832	-10
7	86.3965	117	10.95	-427.871	-546.674	10
8	82.5274	116	10.95	-433.909	-527.603	10
9	82.4756	281	10.95	-402.705	-559.904	10
10	81.5459	355	10.95	-402.705	-559.904	-10

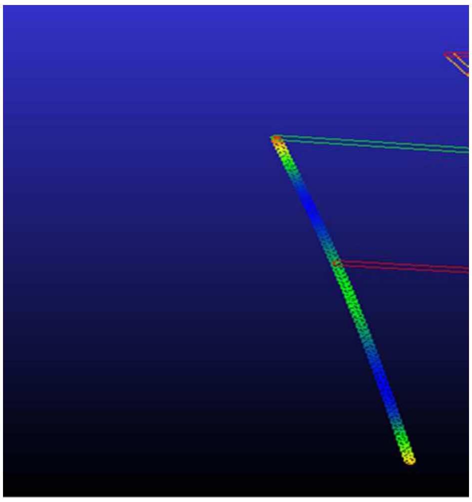


Figure 11: Fail in Robot Leg in part 9 at N=110 rpm

Model picture in ADAMS shows the stresses and positions of stresses. It shows the fail in robot leg in part 9.

Table 6: Shows Stresses and Velocities Values in Part 9, Part 5

Part No.	Velocities values(rpm)	Stresses values(N/mm^2)
Part number 5	44	3.1119
Part number 9	44	2.7854
Part number 5	88	107.3211
Part number 9	88	53.7721

RESULTS & CONCLUSIONS

The numerical analysis has been simulated by using MATLAB as well with ADAMS software.

References points A,B of the mechanism displacements, velocities, and accelerations have been found considering the links are elastic members with the help of ADAMS.

The dynamic analysis plots found by ADAMS for the B,A points(part5, and part9). The increasing in gradually in velocity showed the limited of speed value.

If the mechanism is allowed to operate beyond this speed(N= 110 rpm) the required path trajectory will not be followed accurately and also jerks might be occurred in the mechanism .

The stresses and deformation develop are high and members may be fail on this speed, and that what really happened in N =110 rpm.

Results from MSC.ADAMS

Here, will see the values for accelerations, displacement and velocities, also the deformation values at the points (A,B) which have been effect because the velocity values as showed on previous work. And it is especially at N=110 rpm, which cannot be ignored.

Table 7: Shows ADAMS Values

Part No.	Velocity (rpm)	Angular deformation (mm)	Translation deformation (mm)	Strain energy ($N.mm^2$)	Stress ($N.mm^2$)
Part 5	110	3.557	6.372	$1.5*10^5$	262.064
Part 9	110	0.711	6.173	$25*10^3$	82.4756

RECOMMENDATIONS

- A physical model of Robot Leg Mechanism can be prepared and inspected experimentally to check its performance by increasing the crank input speed. Feedback control system can be incorporated to make sure the required trajectory of the mechanism at higher speed remains unaffected. Traction force due to contact between foot and ground and friction at joints can also be incorporated in the analysis.
- Increase the actuators number and choose a physical model of robot leg mechanism with increasing in velocity values.

- Different across section of members can be test.

REFERENCES

1. Ottaviano E., Ceccarelli M., Tavolieri C.,A.Nardelli “A Design of a New Leg-Wheel Walking Robot” Proceedings of the 15th Mediterranean conference on control &Automation, 2007,Athens-Greece.
2. Conghui L., Ceccarelli M., Giuseppe C. “Design and Simulation of Legged Walking Robots in MATLAB Environment” LARM: Laboratory of Robotics and Mechatronics, University of Casino, Italy.
3. Conghui L., Ceccarellia M., Yukio T. “Operation Analysis of a One-DOF Pantograph Leg Mechanisms” 2008, 17th International Workshop on Robotics in Alpe-Adria-DanubeRegion September 15-17, 2008, Ancona, Italy.
4. K. Gouthami, K. Madhava Reddy “Design and Analysis of a Walking Robot Leg Mechanism at High Speeds with a Fully Rotative Actuation”, 2013, International Journal of Computer Trends and Technology (IJCTT), volume 4, Issue 8.
5. Hirose S., Kunieda O. “Generalized Standard Foot Trajectory for a Quadruped Walking Vehicle” The International Journal of Rob. Research, Vol. 10, No. 1, 1991, pp. 3-12.
6. Song S. M., Lee J. K, Waldron K.J. “Motion Study of Two and Three Dimensional Pantograph Mechanisms” Mech. and Mach. Theory, 1987.
7. G.V. Phani Babu & N. Amara Nageswara Rao, “Design and Analysis of a Low Cost and Easy Operated Leg Mechanism For A Walking Robot” 2012, International Journal Mechanical and Industrial Engineering (IJMIE), Vol-2, Issue-1.
8. Hamid Mehdigholi and Saeed Akbarnejad,(2008) “Optimization of Watt’s Six-bar Linkage to Generate Straight and Parallel Leg Motion” in the Journal of Humanoids, Vol. 1, No. 1, pp. 11-16.